WHITE PAPER

PRODUCTION SCHEDULING BASED ON OPERATOR'S SKILL AND JOB REQUIREMENTS

CASP

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EXECUTIVE SUMMARY

Future manufacturing will be characterized by the complementarity between humans and automation, especially regarding the production of highly customizable products. This requires new methods and tools for the design and operation of optimized manufacturing workplaces in terms of ergonomics, safety, efficiency, complexity management and work satisfaction. Furthermore, equipment providers are always looking for ways to extend the services offered to their end user by providing such tools tailored to their products and their end user's needs. This paper presents such a tool for addressing the need of production scheduling and/or rescheduling passed on the available personnel skills matched with the jobs that are required by end user's ERP systems.

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INTRODUCTION

As living standards improve, it is increasingly evident that the era of mass production is being replaced by the era of market niches which turned flexibility in an increasingly important attribute for manufacturing. The fluctuant demand urged industry today to create an attractive yet flexible workplace for the years to come, in order to cope with the changes in product diversity and production volume. The link between employees' wellbeing and productivity has been widely investigated through the years and proved that job satisfaction is a valuable characteristic that is not fully valued by the production managers. Therefore, workforce satisfaction as well as skill development draws more and more attention by the companies, which strive for achieving positive working state to improve organizational performance and productivity. Skill assessment and adaptability of the working environment to various employee profiles is another way to bridge the gap between intensive work and positive psychology during the shift. Towards that end, a competence repository in each company can provide a credible human resource categorization relevant to every member's experience. This paper presents a production scheduling approach which aims to adapt the production requirements coming from company's ERP system based on the experience level of the operator. Through the proposed application, jobs will be classified with the appropriate information defined by the required skills for accomplishment and operators with their individual competences. Section 2 describes the methodology, Section 3 the implementation of the system and Section 4 the evaluation of the application. In the last section, the conclusions and the future work are mentioned.

INDUSTRIAL PILOT

The scenario for the pilot is regarding a press brake machine, specifically a fast, accurate, non-hydraulic bending machine. To anticipate the market demands and compete globally machine manufacturers need to continue improving a) the product for ease of use and b) the process to adapt in real time the production (job list) to the skills of human (training, experience, physical or cognitive disabilities, etc.) and automation (setup, performance, etc.) resources available.

The main tasks for the correct use of the machine are:

- Programming: Before working with the machine a programming step is required. The user selects a series of configuration options indicating the setup to be used, the type of bending to be performed, the tools on the machine, etc.
- Setup: In order to complete the machine setup, the user has to inset a series of dies and punches into the appropriate slots.
- Position the sheet metal on the die.

This type of semi-automatic machines always requires a human operator (human resource). To meet the needs of production, the standard approach generates a job list (JobList#001) that considers the due dates requested by the customer and the necessary setup machine for each panel to be produced. This job list generates by a standard approach can be in general realized with fully trained human resources without any physical or cognitive disability. The problems that are needed to be solved is when we have to produce the panels of a job list generated by a standard approach using available resources that are not fully trained or have physical or cognitive disabilities. In order to realize an existing joblist with resources that have physical or cognitive disabilities and/or are not fully trained the job list assignments have to be reconsidered based on the skill matrix of the available resources.

The following information coming from the legacy systems of an equipment builder supplier are required in order to solve the problem:

1) Products to be produced
2) Tasks to be executed & Skills requirements
3) Available resources & Resource capabilities

MODELLING APPROACH

The models that are need to be build are of two basic categories. The facility model including the available operators as resources and the workload model including job details.

Facility Modelling

The facility of the end users is modeled as a two-level hierarchy. The facility is consisted by an arbitrary number of work center in which each work center is consisted by an arbitrary number of resources. Resources is consisted by the machine operators, robots or additional equipment like bending-follower (a tool assisting in manipulating big metal sheets).

Further more for each resource a set of capabilities are defined. These capabilities are (Figure 1):

- Capacity: This characterizes the availability of the resource as well as how many pieces can simultaneously handle. For the human operators and the rest of the resources in this case this value varies from 1 to 0 indicating if the resource is available in the shift or not.
- Maximum dimension: This characterizes the maximum dimension that a resource can handle in mm.
- Maximum Weight: This characterizes the maximum weight that a resource can handle in kg.
- Panel Bend Complexity: This characterizes the capability of the resource to perform complex bends. The values are: Advanced, Intermediate and Elementary.
- Machine Tools Setup Complexity: This characterizes the capability of the resource to perform complex machine setups. The values are: Advanced, Intermediate and Elementary.
- Bending Follower Setup: This characterizes the capability of the resource to work with the Bending Follower tool. The values are: Yes/No.
- Anthropomorphic Arm Setup: This characterizes the capability of the resource to work with the Anthropomorphic Arm tool. The values are: Yes/No.
- Work In Night Shifts: This characterizes the capability of the resource to work in shifts during the night. The values are: Yes/No.

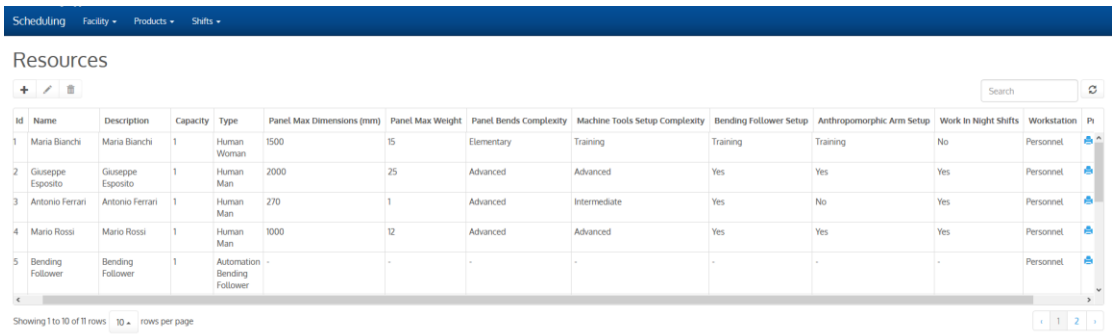

Figure 1 Resources capabilities (skills matrix)

Workflow Modelling

The workflow is modelled as a set of jobs linked together with a sequence number as derived from legacy ERP system (Figure 2). Each job in the job list contains characteristics which allows selection of resource able to perform them. Specifically, the following characteristics are required:

- Width & Height of the panel to be bended in mm.
- Weight of the panel in kg
- Bending Complexity (Advanced/Intermediate/Elementary)
- Setup Complexity (Advanced/Intermediate/Elementary)
- Bending Follower required (Yes/No)
- Anthropomorphic Arm required (Yes/No)

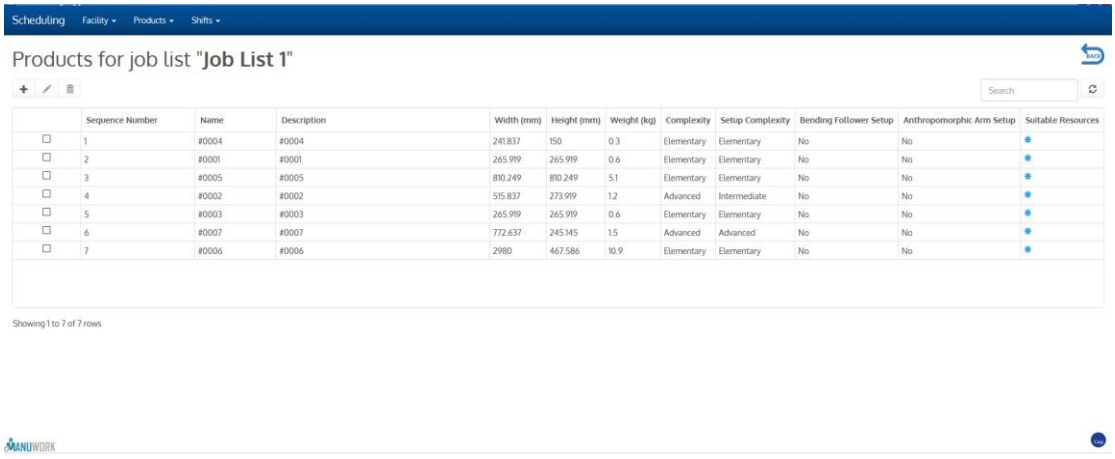

Figure 2 Job List

Finally, for each suitable resource the processing time is required. The result is shown as a Gantt Chart (Figure 3)

IMPLEMENTATION

For the implementation a web application has been developed. The application has been developed using the Spring framework and specifically Spring MVC. The user interface was developed with the Bootstrap 3.0 framework for adaptiveness in all devices ranging from desktops to phablets. The database used is deployed in MySQL 8 and data services with rest interfaces.

Scheduling Algorithm

The scheduling module takes care of optimizing the overall matching of production requirements and available personnel by reorganizing production accordingly. In the core of the scheduling module lies a heuristic algorithm. The algorithm discretizes time into decision points (usually when a resource becomes idle), and at each decision point a number of alternatives are created and evaluated, which guides the algorithm to the next decision point until all jobs that can be performed have been assigned to resources. The alternatives at each decision point are evaluated based on time criterion and a utility value is generated characterizing the alternative quality. The algorithm chooses the alternative with the best utility value and continues to the next decision point.

The heuristic algorithm is governed by three parameters that affect the quality of the solution, as well as the performance of the algorithm in terms of time needed to find a suitable solution. These are the maximum number of alternatives at each decision point, the samples taken into consideration for evaluating the alternative, and the "decision horizon" parameter that controls how far into the future the algorithm should search for the generation of alternatives. These are set empirically in the beginning of the installation, and, with a "trial and error" process, are fine tuned to fit each end user needs.

EVALUATION

The pilot involved two persons of the engineering department. The demonstration included the configuration/usage and output of the tool (Figure 3). At the end of the demo feedback from the participants have been gathered in the form of questionnaires. As a conclusion the application is found easy to use but friendliness and efficiency can be further enhanced by adding graphical elements for the output KPI's (Mean Tardiness, Mean Flowtime) and parameterize the job and operator skill matrices in order for the app to be usable to different type of Machine tools.

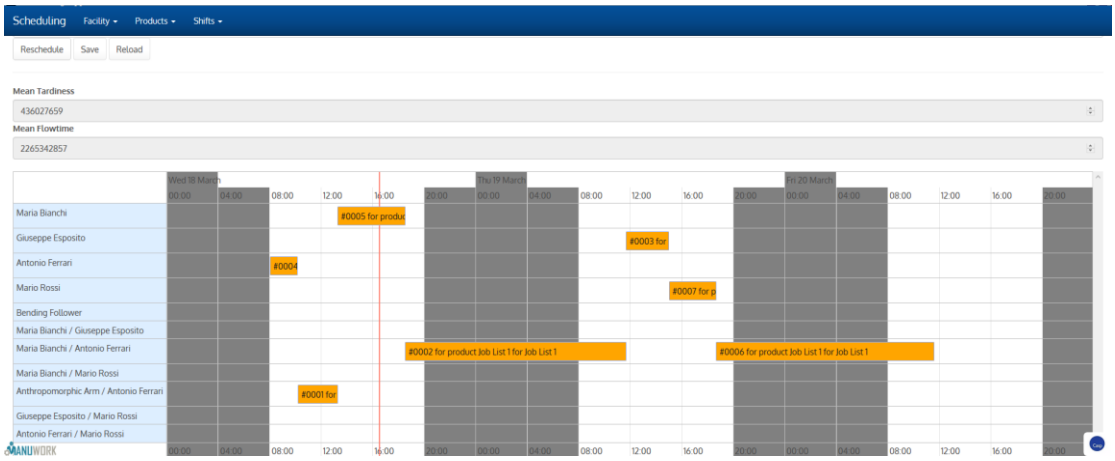

Figure 3 Scheduling App output

DISCUSSION AND CONCLUSIONS

The Scheduling tool got important feedback that helped to become more ready for the market by applying parameterization and friendliness measures. In the near future these developments will be implemented to showcase readiness for the tool to reach the market.

ACKNOWLEDGEMENTS

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